BLOCK I
Combat Maneuvering: Applied Dynamics That Could Save Your Life

Block I Reading Assignment Legend:

Shaw = Fighter Combat: Tactics and Maneuvering
11-F16 = F-16 Combat Fundamentals
Bretana = F-4 Air to Air Reference Text

Bold and Underlined = Read all of assignment in detail!
Normal type = Skim

LESSON 1 – INTRODUCTION
(Pick up Problem Set 1)
How does physics help one be a better combat pilot?

Reading:
Shaw **pp. ix-xiii, pp. xvii-xviii**, Ch. 1
11-F16 **Sec 1.1(p. 8)**, Glossary (pp.291-296)
Bretana Ch. 1 (pp. 1-5)
Problems/Questions:
None
Objectives:
1-1 Understand how the class will be administered.
1-2 Meet other students in the class

LESSON 2 - REVIEW OF "FOUR-FORCE PHYSICS"
Knowing a little aerodynamics really can help you win the fight.

Reading:
Shaw **pp. 387-417**
Bretana pp. 6-7
Problems/Questions:
Work on Problem Set 1
Objectives:
2-1 Understand why maneuvering is needed in aerial combat.
2-2 Know the four primary forces of aerodynamics.
2-3 Understand how lift, drag, thrust and weight are used for maneuvering in combat.
2-4 Know the definition of "G's" and how they affect aircraft performance.
2-5 Know how to read a V-n diagram.

LESSON 3 - TURN PERFORMANCE

The point of all maneuvering is to get into weapons parameters or out of an adversary's weapons parameters (if you made a mistake). A little pre-flight study can show you how to best be able to take or avoid the first shot.

Reading:

Shaw **pp. 86-89**, **pp. 387-417**
11-F16 **Sec 4.6.5.2 (pp. 46-53)**
Bretana pp. 8-11

Problems/Questions:

Work on Problem Set 1

Objectives:

3-1 Know how to calculate and what factors affect an aircraft's turn rate.
3-2 Know how to calculate and what factors affect an aircraft's turn radius.
3-3 Know the definition of corner velocity and how it affects an aircraft's combat performance.
3-4 Be able to compare an aircraft's turn performance in a level turn and a non-level turn.
3-5 Know the definitions of radial g and turn circle.

LESSON 4 - ENERGY MANEUVERING

The pilot with the best energy management skills will usually win the fight.

Reading:

Shaw **pp. 175 (last paragraph)-177**
11-F16 **Sec 4.6.5.3-4.6.5.3.3 (p. 54)**
Bretana pp. 12-20

Problems/Questions:

Work on Problem Set 1

Objectives:

4-1 Understand how conservation of mechanical energy is related to aerial combat.
4-2 Know which of the four aerodynamic forces are non-conservative.
4-3 Understand what specific excess power is and how it is used in aerial combat.
4-4 Be able to interpret specific excess power overlays for a single aircraft and an aircraft comparison for combat.
4-5 Know the three primary factors that help you accelerate to regain lost energy in the shortest time.

LESSON 5 – PRINCIPLES OF BASIC FIGHTER MANEUVERS (BFM)

Now that you know how to use the physics of flight to do some calculations, let's see how it's actually employed during basic fighter maneuvers (BFM).

Reading:

Shaw **pp. 62-74, pp. 15-30**
11-F16 **Sec 4.1 (p. 36), 4.6-4.6.7(pp. 39-60)**, 4.14-4.14.2 (p. 110), 4.14.4 (pp. 115-116), 4.14.6 (pp. 118-119)
Bretana pp. 71-80

Problems/Questions:

Work on Problem Set 1

Objectives:

5-1 Understand the three factors: range, aspect angle, and angle off (heading crossing angle), and how they relate to positional advantage.
5-2 Know the three types of pursuit curves and how they are used.
5-3 Understand what a High Yo-Yo is and when to use it during an aerial engagement.
5-4 Understand what a Low Yo-Yo is and when to use it during an aerial engagement.
5-5 Understand what a Lag roll is and when to use it during an aerial engagement.
5-6 Know the definition of a Weapons Employment Zone (WEZ).
5-7 Know the three requirements for a stabilized guns track.

LESSON 6 - LOW ASPECT BFM
(Problem Set 1 Due. Pick up Problem Set 2)
Today we will continue discussing close-in offensive and defensive BFM -- endgame maneuvers to kill and/or avoid being killed.

Reading:
Shaw pp. 74-82, **pp. 82-97, pp. 23-31**
11-F16 **Sec 4.7-4.8.7 (pp. 60-76)**
Bretana pp. 71-80, pp. 85-94
Problems/Questions:
Finish Problem Set 1
Objectives:
6-1 Know how to properly enter a bandit's turn circle.
6-2 Know when and how to properly separate.
6-3 Understand what a guns jink is as when to use it in an aerial engagement.
6-4 Understand what Flat Scissors, Rolling Scissors, and High/Low Stacks are and when to use them during an aerial engagement.
6-5 Understand what a Defensive Spiral is and when to use it during an aerial engagement.

LESSON 7 – APPLICATION EXERCISE 1
(Bring a 3.5" computer disk to class)
We'll use an Excel spreadsheet to model horizontal and vertical fights. Which fighter will win?

Reading:
"The Problem of the Pullout" Handout
Problems/Questions:
Work on Problem Set 2
Objectives:
7-1 Understand how Euler's method can be used to model aircraft performance.
7-2 Be able to compare an aircraft's performance in a level turn versus a vertical turn.

LESSON 8 – APPLICATION EXERCISE 1 CONTINUED
(Bring a 3.5" computer disk to class)
OK, so modeling something this complex isn't that quick and easy. You'll now get a chance to finish up your first application exercise.

Reading:
"The Problem of the Pullout" Handout
Problems/Questions:
Work on Problem Set 2 and Application Exercise 1
Objectives:
8-1 Understand how Euler's method can be used to model aircraft performance.
8-2 Be able to compare an aircraft's performance in a level turn versus a vertical turn.

LESSON 9 - HIGH ASPECT BFM
(Application Exercise 1 due)
Low aspect stuff is the endgame of many a furball, but how did you miraculously end up on that guy's tail in the first place? Weapons parameters, aircraft capabilities, and energy states drive the tactics we use to win the fight.

Reading:
Shaw **pp. 74-82,** pp. 98-138
11-F16 **Sec 4.9-4.9.5 (pp. 77-82)**
Bretana pp. 80-84, pp. 41-48
Problems/Questions:
Finish Application Exercise 1, Work on Problem Set 2
Objectives:
9-1 Understand what Lead Turns are.
9-2 Know the difference between a One-Circle Fight (Nose-to-Nose Turn) and a Two-Circle Fight (Nose-to-Tail Turn).

LESSON 10 – Energy vs. Angles
High aspect stuff is pretty complicated, so we'll use this lesson to make sure your decision to go one circle or two circle is based on sound tactical (i.e., sound physical) reasons.

Reading:
Shaw **pp. 98-138**
Problems/Questions:
Work on Problem Set 2
Objectives:
10-1 Understand what an angle fighter's primary tactics are and the physics principles used for this method of aerial combat.
10-2 Understand what an energy fighter's primary tactics are and the physics principles used for this method of aerial combat.

LESSON 11 – BASIC INTERCEPTS
So now we know how to win a dogfight. How do we go about transforming a radar contact at 50 miles into fireball?

Reading:
Shaw pp.31-61, **pp.346-355**
11-F16 **Sec 4.13-4.13.5.3 (pp. 105-110)**

Problems/Questions:
Work on Problem Set 2
Objectives:
11-1 Understand the steps of a baseline intercept.
11-2 Know the definition of Collision Antenna Train Angle (CATA).
11-3 Understand the factors that affect an air-to-air missile Weapons Employment Zone (WEZ).
11-4 Know the definitions of F-pole and E-pole.
11-5 Know the basics of Radar Missile Defense (RMD) and Infrared Missile Defense (IRMD).

LESSON 12 – AIR-TO-AIR TOURNAMENT

So you think you're hot stuff now that you've studied all of this fighter physics? You can talk the talk, but can you walk the walk? We'll see in a 1v1 computer simulation tournament. To the best pilots go the spoils!

You'll be flying simulated F-15Es in mortal combat on two linked computers. The sim controls will be set to the expert mode, so this exercise won't play like some arcade game…you'll need to watch your load factor carefully, and monitor your energy state at all times. We'll split the class into two forces: Red and Blue. The winning side will be handsomely rewarded!

Reading:

None

Problems/Questions:

Work on Problem Set 2

Objectives:

12-1 Understand how the principles of physics drive the tactical employment of aircraft.

LESSON 13 – AIR TO GROUND BASICS

Controlling the skies is important only in so much as to allow us to do the mission that will win the war – bombing the snot out of the enemy.

Reading:

11-F16 **Sec 5.5-5.5.3 (pp. 125-127)**

F-4 Conventional Weapons Delivery Handout **Sec 2-1 through 3-2 (pp 2-1 to 3-6)**

Problems/Questions:

Work on Problem Set 2

Objectives:

13-1 Be familiar with general types of surface-to air threats.

13-2 Know the advantages and disadvantages of low and medium altitude ingresses.

13-3 Understand the basic types of bomb deliveries and the advantages and disadvantages of each.

LESSON 14 – AIR TO GROUND ERROR MINIMIZATION

Those Eagle-driver prima donnas may think air-to-air is all there is, but that's because they've never experienced the thrill of a 45-pop delivery. If you've ever felt the "need for speed", low-level is where it's at!

Reading:

11-F16 **Sec 5.6.6 (p. 134), Sec 5.7.8-5.7.8.6 (pp. 139-145)**

F-4 Conventional Weapons Delivery Handout **Sec 3-3 (pp. 3-6 to 3-11)**

Problems/Questions:

Work on Problem Set 2

Objectives:

14-1 Understand the 6 factors that can cause manual bombing errors.

14-2 Understand the 3 main sources of computed bombing errors.

LESSON 15 – REVIEW
(Problem Set 2 due)
Today we will rehash all of the topics we've covered so far in preparation for a fairly comprehensive Graded Review. This is no spoon-feeding session—you'll be asking the questions, so come prepared!

Reading:
Review Lessons 1-14
Problems/Questions:
Finish Problem Set 2
Objectives:
15-1 Prepare for GR 1

LESSON 16 – GUEST SPEAKER
This lesson will be dedicated to hearing the opinions of a famous fighter pilot whom many of you will know.

Reading:
Review lessons 1-14
Problems/Questions:
None
Objectives:
16-1 Recognize that a solid understanding of physical principles is a quality of many successful fighter pilots

LESSON 17 – GRADED REVIEW ONE

Reading:
Review lessons 1-12
Problems/Questions:
None

BLOCK II
Offensive Electronic Warfare:
How to Control and Use The Electromagnetic Spectrum to Win the Fight

Block II Reading Assignment Legend:

Stimson = Introduction to Airborne Radar

Bold and Underlined = Read all of assignment in detail!
Normal type = Skim

LESSON 18 – GR Debrief
(Pick up Problem Set 3)
Part of training to fight is learning from your mistakes…

Reading:
None
Problems/Questions:
None
Objectives:
18-1 Learn from your mistakes

LESSON 19 – AN INTRODUCTION TO ELECTRONIC WARFARE
(Pick up Problem Set 3)
The adversary you can't find is the hardest one to fight!

Reading:
Stimson **Ch. 1-2**, Ch. 3
Shaw **pp. 40 (last paragraph) to 43**
Problems/Questions:
None
Objectives:
19-1 Know the definition of electronic warfare.
19-2 Know the primary portion of the electromagnetic spectrum used for aerial combat and how it's used.
19-3 Understand the basics of radar operations.
19-4 Know the basics components of a radar and how they work.

LESSON 20 - REVIEW OF ELECTROMAGNETISM

Understanding the propagation of electromagnetic (EM) waves is essential to understanding radar. Knowing how to analyze these waves makes understanding more advanced concepts much easier.

Reading:

Stimson **Ch. 4, Ch.6**

Problems/Questions:

Work on Problem Set 3

Objectives:

20-1 Understand how EM waves are produced.
20-2Understand how Maxwell's Equations in a vacuum predict EM waves.
20-3 Know the different variables associated with the wave equation and what they stand for.
20-4 Know the definition of a decibel.
20-5 Understand how to use the decibel to show relative intensity.

LESSON 21 – APPLICATION EXERCISE 2

(Bring a 3.5" computer disk to class)

We'll analyze a variety of waveforms to break complicated waves into simple, single-frequency components

Reading:

Stimson **Ch. 5**

Problems/Questions:

Work on Problem Set 3

Objectives:

21-1 Understand how phasors can be used to represent EM waves.
21-2 Understand how phasors are used to analyze complex EM waves.

LESSON 22 – TARGET RESOLUTION

(Application Exercise 2 Due)

"Cougar, I'm going to break high right to see if there's a trailer…" So how do we know whether that blip is more than one enemy?

Reading:

Stimson **Ch. 7, Ch. 8**

Problems/Questions:

Finish Application Exercise 2, Work on Problem Set 3

Objectives:

22-1 Be able to describe several reasons why radars use certain frequencies.
22-2 Know the reason why radars have a main lobe and side lobes.
22-3 Know how a radar's beam width is defined.
22-4 Understand how angular resolution is determined.
22-5 Know the factors that degrade angular resolution.
22-6 Know the factors that enhance angular resolution.
22-7 Understand antenna gain.

LESSON 23 – APPLICATION EXERCISE 3

Today we're going to accomplish an ESM mission. We're going to investigate what a MiG-29's CW illuminator feed horn antenna's radiation pattern looks like. The lives of many airmen depend on your results!

Reading:

Stimson Ch. 7, Ch. 8

Problems/Questions:

Work on Problem Set 3

Objectives:

23-1 Understand how a directional antenna produces a radiation pattern and what factors affect the shape of pattern.

23-2 Know how to determine the beamwidth of an antenna from its radiation pattern.

LESSON 24 – RANGING SCHEMES

(Application Exercise 3 due)

Time to learn some nomenclature for pulsed EM waves, examine the factors that determine a radar's maximum detection range and find out what determines range resolution.

Reading:

Stimson **Ch. 9, Ch. 10, Ch. 12 (exclude sections on ghosting)**

Problems/Questions:

Finish Application Exercise 3, Work on Problem Set 3

Objectives:

24-1 Be able to identify the different portions of a pulsed EM wave in the time domain.

24-2 Understand how noise and the power of the target's return effect maximum detection range.

24-3 Know what maximum unambiguous range is and what affects it.

24-4 Understand methods used to increase a radar's maximum unambiguous range.

24-5 Know how range resolution is determined and what factors enhance it.

24-6 Be able to determine a radar's resolution cell.

LESSON 25 – RANGING AND RESOLUTION

(Problem Set 3 due; Pick up Problem Set 4)

Last lesson we saw that pulse width was ultimately the limiting factor in target range resolution. We now investigate several techniques for overcoming that limitation.

Reading:

Stimson **Ch. 13 (pp. 163-169), Ch. 14 (exclude sections on ghosting)**

Problems/Questions:

Finish Problem Set 3

Objectives:

25-1 Understand the concept of "chirp".

25-2 Be able to calculate the range resolution of a chirped pulse.

25-3 Understand how range can be indirectly measured through linear FM modulation of the radar signal.

25-4 Be able to calculate target range using FM ranging techniques.

LESSON 26 – THE DOPPLER EFFECT

In previous lessons, we've hinted at the huge effects of target and shooter velocity on radar returns. In this lesson we'll see just what those effects are.

Reading:

Stimson **Ch. 15**

Problems/Questions:

Work on Problem Set 4

Objectives:

Understand what the Doppler effect is and what causes it.
Understand how a Doppler shifts occurs for a moving radar.
Understand how phasors can be used to represent a Doppler shift in EM waves.
Be able to calculate the Doppler shift of a radar return.

LESSON 27 – DOPPLER'S EFFECT ON SPECTRA

In this lesson, we'll examine how Doppler techniques simplify the processing of some data while they make other analyses much more complicated.

Reading:

Stimson **Ch. 16-17**

Problems/Questions:

Work on Problem Set 4

Objectives:

27-1 Understand what a coherent and an incoherent pulse is.
27-2 Understand the purpose of a Fourier transform.
27-3 Know what is meant by a frequency spectrum.
27-4 Understand how pulse duration affects the pulsed spectrum.
27-5 Understand how the number of pulses affects the pulsed spectrum.
27-6 Understand how pulse repetition frequency affects the pulsed spectrum.

LESSON 28 – APPLICATION EXERCISE 4

(Bring a 3.5" computer disk to class)

In this computer exercise we will analyze several pulses to investigate and attempt to minimize the spectral broadening and maximize the line spacing that pulsing creates.

Reading:

Stimson Ch. 16-17

Problems/Questions:

Work on Problem Set 4

Objectives:

28-1 Understand the different ways a pulsed spectrum can be changed.
28-2 Understand how to minimize the line width and maximize the line spacing of a pulsed spectrum

LESSONS 29 – APPLICATION EXERCISE 4 CONTINUED
(Bring a 3.5" computer disk to class)
Yes, this is complicated! Therefore, we will spend some more time analyzing several pulses to investigate and attempt to minimize the spectral broadening and maximize the line spacing that pulsing creates.

Reading:
Stimson Ch. 16-17
Problems/Questions:
Work on Applications Exercise 4 and Problem Set 4
Objectives:
29-1 Understand the different ways a pulsed spectrum can be changed.
29-2 Understand how to minimize the line width and maximize the line spacing of a pulsed spectrum

LESSON 30 – DOPPLER SHIFTS AND RANGE RATE
(Application Exercise 4 due.)
So far, we've seen how the Doppler effect works and how it is affected by pulsing a signal. Now we'll see how Pulse-Doppler radars use the frequency information.

Reading:
Stimson **Ch. 18, 21**, Ch. 25
Problems/Questions:
Finish Application Exercise 4, Work on Problem Set 4
Objectives:
30-1 Understand the purpose of Doppler filters and how they affect pulsed-Doppler radar performance.
30-2 Understand what is meant by dynamic range.
30-3 Know the two methods used to measure range rate.
30-4 Understand what Doppler ambiguity is.
30-5 Understand the methods used to resolve Doppler ambiguities.
30-6 Understand the advantages and disadvantages of low, medium and high PRFs.

LESSON 31 – CLUTTER
So far, we've only investigated how radar returns from our intended target. Adding ground to the picture complicates things a lot. We'll take a quick survey of how ground clutter affects radar returns and ways to minimize its effects.

Reading:
Stimson **Ch. 22, Ch. 23**
Problems/Questions:
Work on Problem Set 4
Objectives:
31-1 Understand the factors that affect the ground clutter.
31-2 Understand ways to minimize ground clutter effects.
31-3 Understand effects of ground clutter on target radar returns.

LESSON 32 – ELECTRONICALLY STEERED ARRAYS

To this point, we've assumed that our radar antenna was a simple parabolic dish that was mechanically pointed at our intended target. This lesson will explain how modern radars don't really have to move at all.

Reading:

Stimson **Ch.37, Ch 38**

Problems/Questions:

Work on Problem Set 4

Objectives:

32-1 Understand the physical processes in a phased array.
32-2 Understand how a phased-array antenna is steered electronically.
32-3 Know the cost and benefits of the phased array design.

LESSON 33 – APPLICATION EXERCISE 5
(Problem Set 4 Due)

In this computer application, we will do an analysis of a one-dimensional array of emitters to determine its beam and steering characteristics.

Reading:

Stimson Ch. 37-38

Problems/Questions:

Finish Problem Set 4

Objectives:

33-1 Understand how the number of emitters affects the beam width and steering.
33-2 Understand how the emitter slit width affects the beam width and steering.
33-3 Understand how the emitter's phase shift affects the beam width and steering.

LESSON 34 – GR Review
(Application Exercise 5 Due)

Next lesson is the GR covering everything we've studied about radar so far, including spatial effects (angular and range res cell dimensions, etc.) and pulse effects (range determination, Doppler sensing, frequency spectra, etc.). Come prepared with questions for the review.

Reading:

None

Problems/Questions:

Finish Application Exercise 5

Objectives:

None

LESSON 35 – GR TWO

Reading:

Review readings for lessons 18-33

LESSON 36 – GR DEBRIEF

Today we'll go over the GR to ensure you understand the material

Reading:

None

BLOCK III
Defensive Electronic Warfare:
Advanced Radar Techniques, Countermeasures, and Passive Sensors

Block III Reading Assignment Legend:

Stimson = Introduction to Airborne Radar

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LESSON 37 – ELECTRONIC SUPPORT MEASURES (ESM)
(Pick up Problem Set 5)
With ESAs, we've just looked at emitting radiation with different phases to control the beam's direction. If we could detect the phase of an incoming beam at different points we may be able to determine the location of the source. Can you say "Wild Weasel"?

Reading:
Stimson **Ch. 36**
Problems/Questions:
None
Objectives:
37-1 Know the definition of ESM
37-2 Know the main method used to accomplish ESM
37-3 Understand the physical processes used in interferometry.

LESSON 38 – ELECTRONIC COUNTERMEASURES (ECM)/ELECTRONIC COUNTER-COUNTERMEASURES (ECCM)
To this point we've built a very solid basis for understanding radar. Now that we know how it works, we can look at ways to defeat it! We'll also look at the continual tug between offense and defense as we examine ways to avoid having your radar defeated.

Reading: Stimson **Ch. 34-35**
Problems/Questions: Work on Problem Set 5
Objectives:
38-1 Know the definition of ECM.
38-2 Know the three methods used to employ ECM.
38-3 Know the main types of jamming and how they affect a radar presentation.
38-4 Know the definition of ECCM.
38-5 Understand the methods used to counter noise and deception jamming.
38-6 Know the most effective ECCM of all.

LESSON 39 – APPLICATION EXERCISE 6 -- BUILDING AN RF JAMMER
Today we will build a simple noise jammer to jam reception of an FM radio station.

Reading:
Stimson **Ch. 14 (through p 180)**
Problems/Questions:
Work on Problem Set 5
Objectives:
39-1 Understand the resonance of an LC circuit.
39-2 Understand the basics of frequency modulation (FM).
39-3 Build a jammer that works.

LESSON 40 – USING THE INFRARED
(Application Exercise 6 Due)
It's just another portion of the electromagnetic spectrum, but it brings up a whole new set of problems. Here, we'll look at several types of IR seekers, seekers for missiles and the holy grail of the IR world, a usable IRSTS.

Reading:
Shaw **pp. 39 (last paragraph) to 40**
Solid State Physics Handout
Problems/Questions:
Finish Application Exercise 6, Work on Problem Set 5
Objectives:
40-1 Know the part of the EM spectrum used for IR threats.
40-2 Understand basic solid state band theory
40-3 Understand the different consideration used for seeker design.
40-4 Understand how an IRSTS is used, why they could be so effective, and their limitations
40-5 Know the different types of IRCM and how they are used.

LESSON 41 – STEALTH
You don't need all that countermeasures stuff if they can't find you!

Reading:
Stimson **Ch. 39, Ch. 42**
Stealth Handout
Review lessons 35-41, Review lessons 1-34
Problems/Questions:
Finish Problem Set 5
Objectives:
41-1 Understand how stealth technology uses EM wave redirection.
41-2 Understand how stealth technology uses EM wave absorption.
41-3 Understand the basic principles of Low Probability of Intercept (LPI) technology.

LESSON 42 – Final Review
(Problem Set 5 due)
Come prepared with questions for the review. I won't have a prepared plan, so if you don't understand a topic, step up to the plate and ask!